Determination of the Bending Strength and Hardness Values of Sisal Fiber Reinforced Polyester Composites

Mutai, A. J[1*], Ogola, W. O[2] and Ondieki, C. M. M[3]
[1]Rift Valley Institute of Science and Technology, P.O Box 7182-20100 Nakuru-KENYA, Phone Number: 0722 981 249,
E-mail: kabonalice@yahoo.com
[2]Kenya Polytechnic University College, P.O Box 52428-00200 Nairobi- Kenya
Department of Mechanical and Mechatronics Engineering,
Phone Number: 0722 906 168, E-mail: wilsonogola@hotmail.com
[3]Multi-Media University College, P.O. Box 30305-00100 Nairobi - Kenya.
Department of Mechanical Engineering
Phone Number: 0722 705 609, E-mail: charlesondieki@yahoo.co.uk
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Abstract

The growing environmental consciousness and understanding of the need for sustainable development has generated interest in the use of natural fibers as reinforcements in polymer composites to replace synthetic fibers such as glass. The aim of this study was to determine the bending strength and hardness values of composite samples from sisal fibers and unsaturated polyester resin as the matrix. Chopped random sisal fibers were mixed with resin at various fiber weight percentages from 5, 10, 15, 20 to 40% sisal fiber. Hand lay- up and cold compression processes were used to produce test samples which were left to cure at 25^0C. The test samples were supported on knife edges and a roller edge central load applied on them for the three-point bend test. The hardness of the samples was tested on a Vickers micro-hardness testing machine. Results show that the 30%wgt fiber content had the highest value of 51.062 MPa for bending strength properties and 16.1 for hardness value while the unmodified sisal fibers recorded a bending strength of 40.382 MPa and a hardness value of 15 at the same fiber content. The modified sisal fiber has a better bonding between the fibers and matrix compared to unmodified sisal fiber therefore the composite samples could bear more load. It was also observed that surface modification of plant fibers result in superior bonding of the fibers and matrix. Sisal leaves produces fibers that could be used in composite manufacturing for use in roofing, partitioning and furniture applications.

Key words: Bending strength, polyester resin, matrix, Agave Sisalana, fibers, composites

Introduction

The growing environmental consciousness and understanding of the need for sustainable development has generated interest in the use of natural fibers as reinforcements in polymer composites to replace synthetic fibers such as glass. However, serious concerns on the level of mechanical performance that can be achieved with these materials are still present because the mechanical behavior of plant fibers as reinforcement can not be easily predicted. The present work described the development of polymer composites consisting of sisal fiber- a natural fiber that is abundantly available in Kenya, as the reinforcing agent and unsaturated polyester as the matrix material. The scope of this study was limited to the determination of the bending strength and hardness values of the composite samples.

Since the 1990s, natural fiber composites such as hemp fiber-epoxy, flax fiber-polypropylene (PP) and china reed fiber-PP emerged as realistic and attractive alternative replacements of the glass-reinforced composite in automotive applications because of low cost and low density. Natural fiber composites offer environmental advantages such as reduced dependence on non-renewable energy and material sources, lower pollutant emissions and lower greenhouse gas emission, enhanced energy recovery and of life biodegradability of components (Joshi *et al*, 2003). Natural fibers such as banana, cotton, coir, sisal and jute have attracted the attention of scientists and technologists for application in consumer goods, low cost housing and other civil structures. These natural fiber composites possess better electrical resistance, good thermal and acoustic insulating properties and higher resistance to fracture compared to synthetic fibers, for example low weight, low density, low cost, acceptable specific properties and they are recyclable and biodegradable. They are also renewable and have relatively high strength and stiffness and cause no skin irritations (Hatgitai *et al*, 2006). They however, also have disadvantages such high moisture uptake, quality variations and low thermal stability. Many studies have been made on the potential of the natural fibers as reinforcements for composites and in several cases the results have shown that the natural fiber composites have good stiffness but the composites do not reach the same level of strength as the glass fiber composite (Oksman *et al*, 2003).

Though many studies have been carried out on natural fiber composite, very little has been done in East Africa though it is endowed with fibrous plants. Very limited information and data have been reported dealing with the mechanical properties of sisal polyester reinforced composites. Sisal fiber is one of the export products of Kenya and developing a useful composite from waste of the factory added value to the sisal plant. And the fact that sisal fiber is obtained directly from natural resource and is cheap makes it even more attractive in terms of sustainability and environmental awareness. The use of sisal fiber also has an economical advantage since the expensive and imported glass fiber can be replaced by sisal fiber.

The main aim of this study was therefore to explore the new natural resources, considering the available abundance of sisal fiber material in Kenya. The study is significant because it explores the potential of the abundant resource from arid and semi arid regions of the country for use as fiber in reinforced composites.

Materials and Methods

In this study, sisal fibers as reinforcement and unsaturated polyester resin as a matrix for composite fabrication were selected. The reinforcing material was the locally available sisal fibers while the binder was unsaturated polyester resin with methyl ethyl ketone peroxide (MEKP) as catalyst, acetone, sodium hydroxide, benzene and ethanol were the modifying and cleaning agents.

The sisal leaves were harvested from Athenai sisal plantation in Mogotio area of Nakuru district and taken to the Athenai sisal factory for the decorticating process. The sisal fibers used for the fabrication of samples were collected from the waste washed-off by the water from the fiber decorticating machine at the factory area. The fibers were thoroughly brushed to remove any remaining cortex and dirt. The brushed fibers were then cut to 6cm in length, weighed to the required percentage fiber content and marked ready for further cleaning and drying. The fibers were cleaned in commercial detergent solution followed by distilled water and then dried in an oven at 100°C for four hours to remove the dirt from the fibers. The fibers used without further cleaning were referred to as unmodified whereas those that underwent further surface cleaning were referred to as modified.

Surface modification of the natural fibers improve the adhesion between the hydrophilic fibers and the hydrophobic resin. Alkaline group of sodium hydroxide (NaOH) and a solution of benzene and ethanol at a ratio of 1:1 were used to surface modify the fibers. The fibers in bundles were soaked in a 5% NaOH solution for 24 hours at room temperature. They were then washed and dipped into alcohol to remove excess chemical solution followed by a thorough wash in distilled water and then oven-dried at 100ºC for four hours. The dried fibers were chopped to length size of 2-4 mm. The chopped fibers then served as treated reinforcing agents in the matrix. The ratio between the polyester resin and hardener for this study was 2% by volume.

Molding design for test sample: The dimensions of the composite samples were 150mm x 15mm x varying thickness.

Fabrication of composite sample: The mould and mold cover were made from mild steel. The mold surface was washed with soap, dried and polished with mirror wax. The releasing agent was then applied on the mold surface followed by the gel coat. The gel coat gives the laminate a shiny smooth finish. The pre-accelerated general-purpose polyester resin was thoroughly mixed with 2% volume MEKP catalyst and applied on the mold. The fibers were then hand-laid on the mold and completely saturated with the resin and then closed, pressed and left to cure at room temperature. Three samples were produced for each percentage fiber content.

Sample test preparation: Test pieces were sawed off from the prepared samples using a hacksaw and in accordance with ASTM standards- D790 for bending strength and ASTM D2240-97 (ASTM 1998) for the hardness value. They were smoothened at the edges prior to subjecting them to the various tests that were undertaken. All the tests were conducted at room temperature. Samples of 127mm × 12.7mm × the thickness of the laminate were prepared for the three-point bend test.

Data Analysis: The experimental tests for bending strength and the hardness value were conducted in Eldoret Polytechnic. Five specimens were prepared for each mechanical test.

The three-point bend test: The three- point bend test was performed on a hydraulic Universal Material Tester, 50 kN (WP 310) at a crosshead speed of 1 mm/min. The test samples were simply supported on knife edges with a central load applied on it (Figure 1).

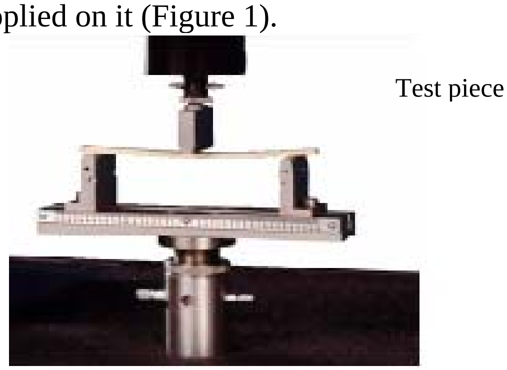

Figure 1: Three-point bend test set up

The instrument used for three-point test could not give measurements on the deflection of the test sample.

Hardness test: The hardness value was conducted using the Vickers micro-hardness tester (Shore Instrument and MFG Co., Freeport, NY). Five readings were taken for each test.

Results and Discussions

Three-point Bending Strength

The bending strength value increased from 31.848 MPa to 51.062 MPa with the increase of fiber loading percentages from 5% to 30 wt. % then dropped to 50.454 MPa at 40% weight. Unmodified sisal recorded a recorded strength of 24.262 MPa to 40.382 MPa for similar fiber loadings as shown in figure 2 and figure 3. The graphs indicate that a maximum was attained at 30% fiber loading.

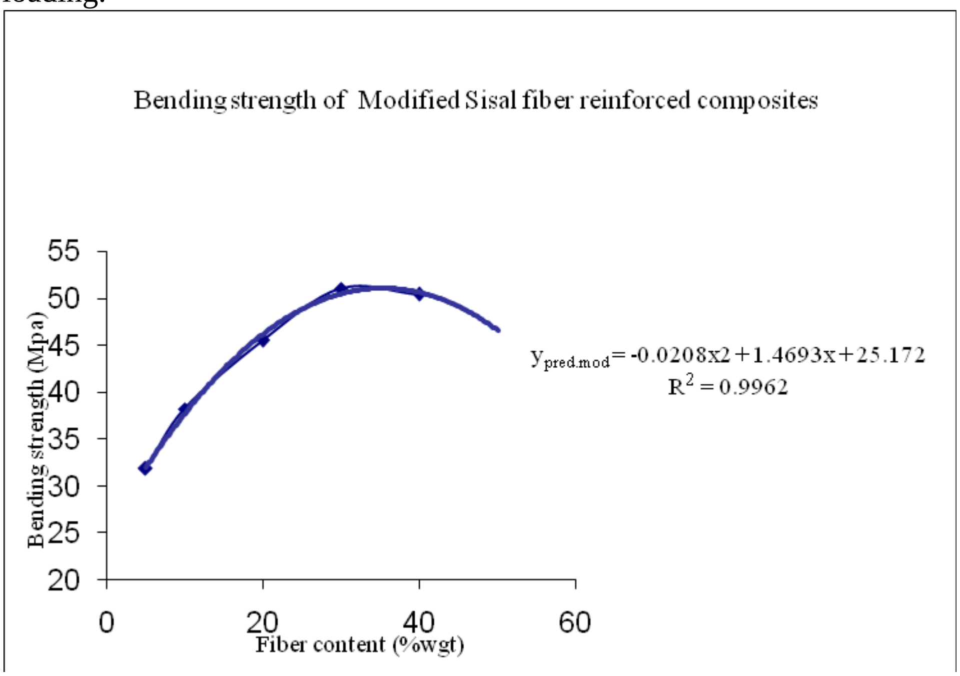

Figure 2: Bending strength of modified sisal fiber reinforced composites

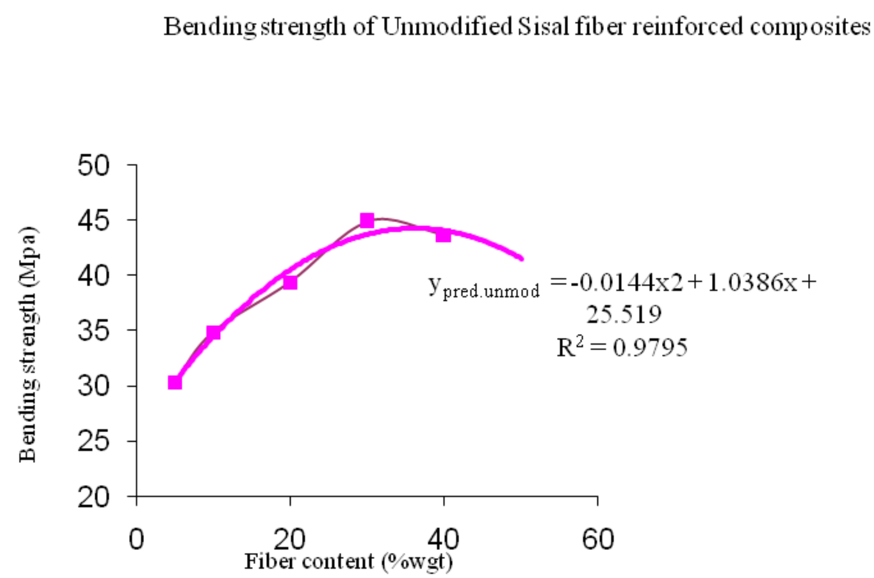

Figure 3: Bending strength of unmodified sisal fiber reinforced composites

Similar trend results though superior were observed by Athijayamani *et al,* (2009) who recorded strength of 88.9 MPa at 30% wgt for sisal treated fibers and 72.7 MPa for untreated fiber, an increase of 22.2%. The fibers were alkali treated for four hours. The deviations of readings in this study could be attributed to fiber properties and the modifying agent. The growing environmental conditions of the fibrous plant have an effect on the fiber properties and these properties in turn determine the composites properties.

Sastra *et al.,* (2006) reported a maximum flexural strength value of 83.308 MPa at 15 wt. % chopped random *Arenga pinnata* fiber reinforced epoxy composite. They also observed that woven roving *Arenga pinnata* fiber composite and long random *Arenga pinnata* fiber composite had superior flexural strength result compared to the chopped random *Arenga pinnata* fiber composite. The test samples of chopped random *Arenga pinnata* fiber composites were easily broken and could not resist bending. They argued that chopped random *Arenga pinnata* fibers caused many voids in the specimen during the curing process of composite materials.

Azis and Ansell (2004) reported superior flexural strength values for the long fibers of hemp and kenaf fibers when compared to the short random of hemp and short random of kenaf fiber composite. These studies conclude that flexural strength values are dependent very much on the fiber orientation and the location of resin-rich areas. Long fibers therefore, tend to give better strength due to their good fiber orientation.

Hardness Value

Hardness is defined as the resistance of a material to deformation, particularly permanent deformation, indentation or scratching where the higher the hardness value the harder the material and the lower the depth of penetration.

The hardness values increased as the fiber content increased for all the composite samples tested. A penetration of 13.58 and 12.1 at 5%wgt, 15.24 and 14.1 at 20%wgt 16.94 and 15.74 at 40%wgt fiber content for modified and unmodified samples respectively were recorded.

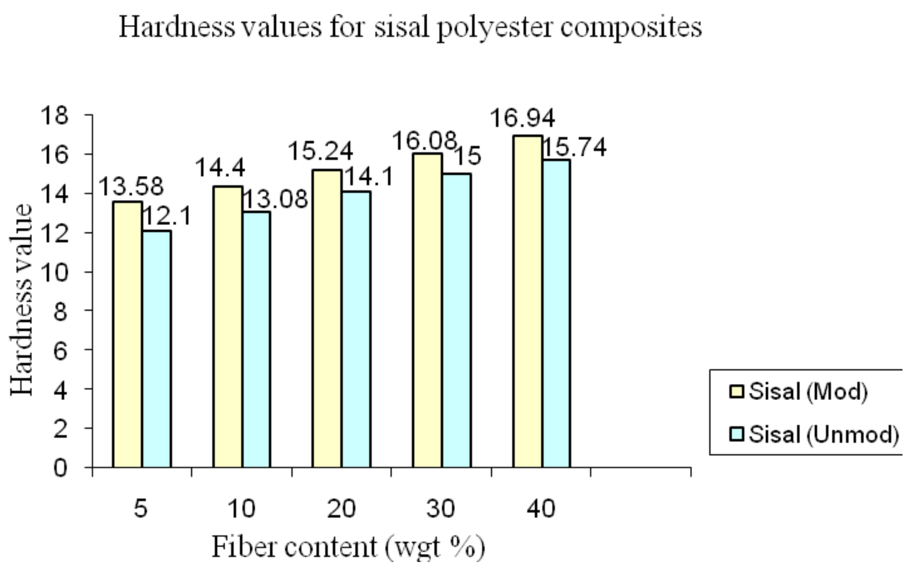

Figure 4: Vickers Hardness numbers for modified and unmodified sisal polyester composite

The modified sisal fiber composites registered higher values than the unmodified fiber composites at all levels. These results imply that surface modification of the fibers improved the bonding between the binding and reinforcing materials.

Similar results were obtained by Sandhyarani *et al.* (2010) in their study of coir fiber reinforced epoxy composites which registered hardness values of 15 for 5mm fiber length and 16 for 30mm length both at 30%wgt fiber loading.

Conclusion and Recommendations

The results of this study showed that useful composites with good properties could be successfully developed using treated sisal as reinforcing agent for thermoset resin matrices. From the discussions of the results it is evident that the strength characteristics of composites depend on type of fiber used and surface modification of the fibers. Surface modification of plant fibers result in superior bonding of the fibers and matrix. Sisal leaves produces fibers that could be used in composite manufacturing for use in roofing, partitioning and furniture applications.

The use of agricultural resources as source of raw material in the plastic industry would not only provide a renewable source, but could also generate a non-food source of economic development for farming and rural areas. Appropriate research and development in the area of agricultural based fibers as reinforcement materials could lead to new value-added, non-food uses of agricultural materials.

It is recommended that properties of fibers and composites comprising other natural fibers besides sisal can be studied in the search for materials that can yield better performance.

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